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14. ABSTRACT

Overall objective is to create and test (using specific applications) a theory and model-based technology for enabling and advancing a cumulative science of "Context-Driven Decision Making (CDDM)." A successful project will advance cumulative CDDM science. Technologically, the effort will show the viability of creating NIMSS software technology that can provide proactive decision support based on the way that decision makers already think, demonstrated via a realistic Naval/Marine Corps warfighting domain.

15. SUBJECT TERMS

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Final Report

CLIN 0005, CDRL B001

Proactive Decision Support via Narrative-Integrated Multi-level Support System (NIMSS)

CHI Project # 14002

Purchase Order: N00014-14-P-1186

(11 July – 30 November, 2014)

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November 30, 2014

FINAL REPORT

Proactive Decision Support via Narrative-Integrated Multi-level Support System (NIMSS)

1.0 Scope/Objective

The overall objective of this effort is to create a novel theoretical framework and technology to provide context-driving support for Command Decision Making. There are four objectives for the proposed program, as enumerated below, and as supported by the specifics tasks defined in Section 2 below.

1.1 Participate in a planning workshop for Proactive Decision Making technology development. Support the efforts of the Navy Program Monitor to develop interactions between and among researchers in the CDDM research community and to develop a roadmap and vision for future CDDM research. Develop analytical inputs related to the NIM/NIMSS model and technology, present and discuss these at the workshop, and report on workshop results from the perspective of the NIM/NIMSS technology research.

1.2. Develop a multi-level computational competence model of decision-makers build, maintain, and represent situational *context*. Integrate multiple existing theories and conceptual models of context that address different (and sometimes overlapping) hierarchical levels of context abstraction, to generate a single cognitive computational model that spans the levels of contexts from perception through to narrative sense-making, and encompasses the cognitive process involved in both: building/maintaining context understanding; and applying context understanding to achieve situational intentions.

1.3 Define coordinated strategies for generating proactive decision support from competence model dynamics. Using the research literature and case examples on human cognitive biases and information processing limitations, identify types of information that can proactively address single or multiple human biases and limitations, and that are computable from the dynamics of competence model. Also identify coordinated strategies for combining the individual decision support functions to support Command decision-making, using the OODA (Observe, Orient, Decide, Act) Loop analytical model of military decision-making.

1.4. Create and demonstrate a proof-of-concept technology for a Narrative-Integrated Multiple Support System (NIMSS) that implements and applies the results of the first objectives 2.2.2 and 2.2.3. Leverage existing COGNET and PAC cognitive modeling technologies and semantic web RDF technology to create a proof-of-concept NIMSS as a general context-driven proactive Command Decision Support technology that could be applied to any domain with domain specific knowledge elements.

2.0 Accomplishments

2.1 Participate in ONR PDS planning workshop

In this task, CHI will attend the workshop and present/discuss these analyses, revising the analyses as needed after the workshop and based on the discussion at the workshop. CHI will deliver, at the end of this task, a copy of the briefing materials and a technical report documenting the above analyses, as revised following the workshop

Progress: Although work has been completed on the workshop, final products from the work shop are enclosed as appendices to this report. These are a technology roadmap (Appendix A), a vignette showing how the NIMSS technology might be applied in a military situation (Appendix B), and a summary of how the CHI Systems/NIMSS technology team plans to collaborate with other Proactive Decision Support program performers (Appendix C). .

2.2 Develop NIMSS Theory & Formalism

In this task, we will develop the NIM context model and develop a Decision Support model based on the underlying context representation. CHI will design and define the computational organization, functional and infrastructural principles and components necessary to provide a computational NIMSS decision support capability

Progress: Work in this final month focused on the representation and management of the representation of time in the NIM context model. There are two issues that were further clarified during this period.

The first issue is that of past versus present. This issues deals with a qualitative representation of time in NIMSS and the NIM context model, which has separate representations for *prior* time, present time, and future time. *Prior time* is involved indirectly via in the representation of the current context model at *present time*, which is constructed through the key-hole (as discussed in last month's report) using lens of all information that has been perceivable by that instance of NIMSS. *Future time* refers to projections of situations and narrative into the future, as a basis for or as part of the process for producing proactive decision support.

The present time representation of context seeks to integrate all past time information into a comprehensive representation of the present context plus a set of plausible narratives that are not contradicted by past-time information. It may, however, include plausible narratives that are incompletely satisfied by past-time information -- incomplete because information needed to fully satisfy them were not available in past-time. This last point (about incompletely satisfied narratives) became clear via efforts to more fully define NIMSS decision support options (see 2.3 below). While narratives that are fully supported by past-time information can be the basis for (in OODA loop terms) *decision* and *action* components of decision support, *incompletely satisfied* narratives can form the basis for *observation* components of decision support. Specifically, such narratives can define additional information that the commander could direct to be collected, so that those narratives can be ruled out (if the heretofore missing data contradicts them) or ruled in (if it supports them). Thus, it became clear how NIMSS, to help the commander in future time, add clarity to the present-time picture by collecting information that was unavailable in past-time.

An additional aspect of past- and present-time dealt with an emerging problem between the situational and narrative representations. This problem had to do with reconciling state-based and process- or action-based representational approaches. We realized that narratives and story-spaces are ultimately representations of streams of action (integrated with other psychological information), while the Situation Awareness levels of our context had been built as representations of state-descriptions of the external reality. Ultimately, these two views are 'duals' of each other, but recognizing this forced us to see why we had been having difficulty in

integrating the situation awareness and narrative views. This, in turn, offered a way forward by integrating them through the story unit construct. It is at the story unit level of the context model hierarchy that we need to link state descriptions (at the perceptual, significance, and projection levels) with a temporal view that allows us to recognize a temporally-ordered set of state information as an indicator (i.e. 'footprint') of part of a story unit (beginning, internal action, end - whatever). This insight removed the final roadblock to a complete computational model of how to fully link the situational and narrative views.

The second issue addressed in this past month is how time, particularly past-time, should be updated, in unitary 'ticks' (of whatever quantum size) or via perception of events that have the potential to change the situational and/or narrative state (i.e., on the basis of" differences that can make a difference"[1]). This has significance particularly to the way in which the virtual machine that implements the NIM Principles of Operation would be built. Here, the work to develop the proof-of-concept software (see 2.4 below) pointed out the implications of these two approaches to the interface of past-time to present-time. While the unitary approach yielded a simpler computational implementation, it also led to a much slower and less scalable approach. The event-based approach, although it required some pre-processing of the knowledge elements involved in a specific NIM application, led to a much more robust and scalable implementation. Thus, we incorporated this (latter) representation.

Finally, we made a final update to the Technical Memorandum defining the structure of the NIM context model framework, its formal notation for representing knowledge, and the principles of operation by which its organic computational processes function. This memorandum represents a working document which incorporates the insights and progress of the current effort that can be a bridge to future research.

2.3 Identify NIMSS Decision Support Interactions

In this task, CHI will identify the necessary Decision Support functions necessary to provide intelligent DSS to the operational end-user. We will develop an OODA-loop approach to deliver the NIMSS-based Proactive Decision Support.

Progress: Work on this task progressed through efforts at praxis via construction of the application vignette (Appendix B) and the proof-of-concept software (2.4 below). These activities, particularly the vignette development, allowed us to explore how the different concurrent concerns of command (i.e., the Observe, Orient, Decide, Act aspects of the OODA loop) could be supported by NIM context model information. Additional theoretical details are summarized above in subsection 2.2 and additional example details are provided in the Appendix B below.

2.4 Develop Initial, Proof-of-concept NIMSS Software

In this task, CHI will develop a canonical representation of the NIM context model and create a data-representation based on it. The contractor shall identify representational requirements needed to support development of representation-building and decision-support agents based on the NIM model. The contractor shall develop a proof-of-concept implement of the context

[1] This quote is from Bateson, G. (1973) Steps to an Ecology of Mind. New York, Ballantine Books, though it is baed on a related concept from MacKay, D. (1969) Information, Mechanism, Meaning. Cambridge: MIT Press.

model, representation-building agents and decision-support agents based and decision agents, leveraging existing software components of the BATON and PAC software systems.

Progress: The development of the proof-of-concept software was completed during the past month. In this final stage, attention was turned to the development of preliminary prototype tools to permit the visualization and inspection of the internal state of the NIM context model during its execution. These tools provide a useful basis for the subsequent development of testing and debugging capabilities for NIMSS in future research, as well as a potential framework for NIMSS to engage in interactions with the NIMSS user concerning the state of the NIMMSS context model. That is, these tools suggest ways in which a NIMSS user could, through additional development, interrogate NIMSS (e.g. in structured natural language) about specific aspects of its context representation and about how specific proactive decision support recommendations were constructed from aspects of the context model. At the end of this effort, all software developed will remain organized into a code repository at CHI Systems, accessible for use in potential subsequent follow-on research.

2.5 Perform Project Management/Reporting

In this task, CHI will provide all deliverables and milestones during this effort including: monthly cost and performance reports and a final Technical Report at the end of the period of performance.

Progress: Internal project management have been maintained and tracked against progress, and all required reports were developed and delivered to ONR. This last report completes the deliverable requirements under the contract.

3.0 Plan for Next Reporting Period

The period of performance for the contract ends with the delivery of this report. In accordance with the possibility of and plans for follow-on effort under a successor contract, we have placed the project working products (i.e., software, working documents, team working note) into an orderly form for a hiatus, from which work could be quickly resume when and if such follow-on support becomes available.

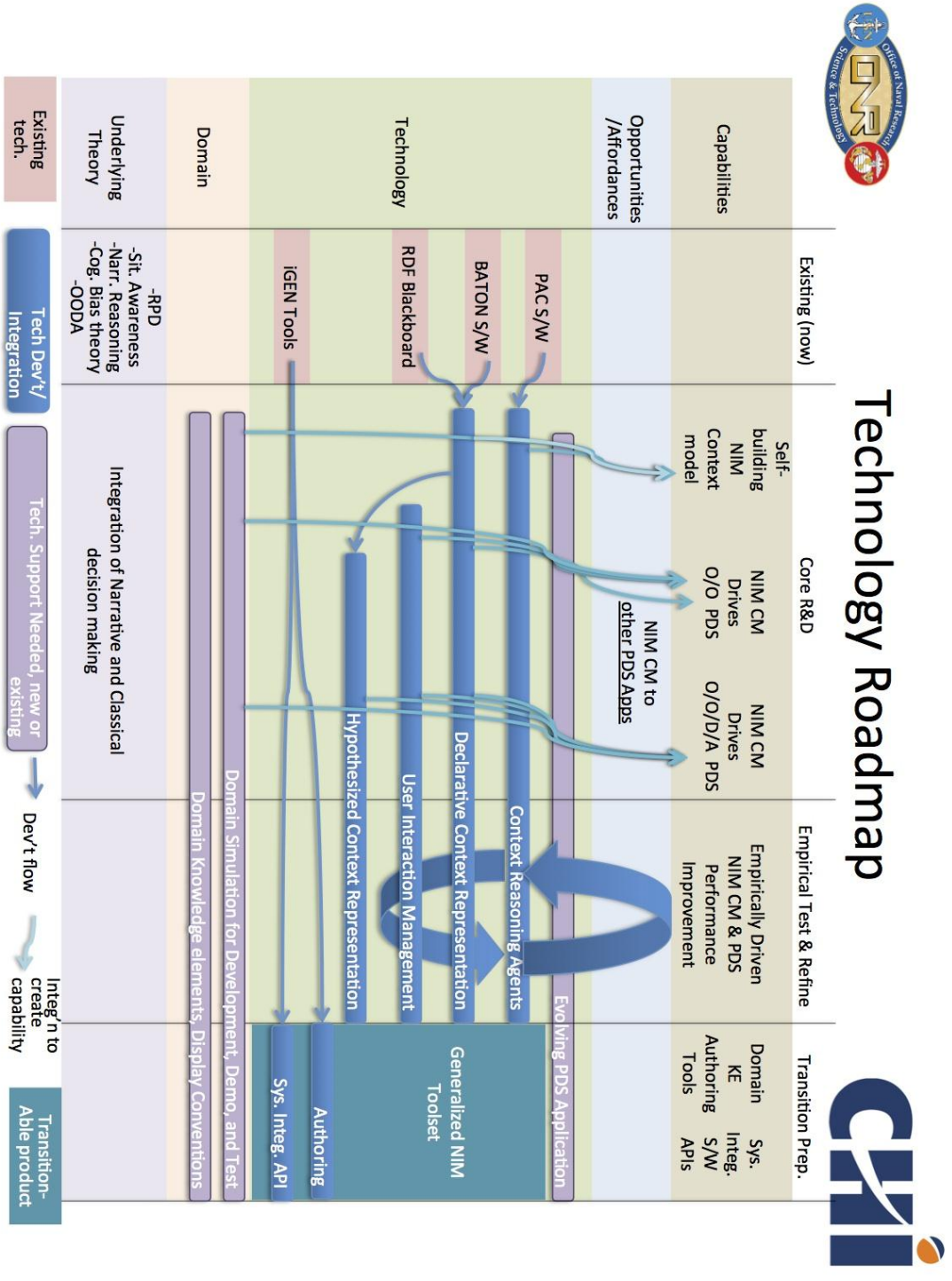
4.0 Financial Data

The Purchase Order was awarded on July 11, 2014, funded in the amount of $149,956 for a period of performance ending on November 30, 2014. The breakdown of fully burdened costs is: Direct Labor: $130,611.00, Travel: $7,257.00, Consultants: $19,345.00.

5.0 Issues

None.

Appendix A. Long-term NIMSS Technology Roadmap



Appendix B. NIMSS Technology-Application Vignette

Mission and Larger Setting

The northern region of Burkina Faso has not only been ravaged by extreme drought but has suffered under competing warlords while the nation and the world has been focused on the violent protests against the government of President Blaise Compaoré and the eventual takeover by the military after Compaoré fled the country. As part of a Marine Expeditionary Unit (MEU) conducting a Humanitarian Assistance (HA) mission in Burkina Faso in the wake of a military coup and return to democracy, Captain Jones, the "A" Company Commander, is tasked to provide security for a mobile NGO food and water distribution. Additionally, Capt Jones has been provided with a medical detachment from the MEU to provide urgent care to the villagers. The HA is to be in a village called Som, about 5 ½ miles west of the Djibo airport and about 120 miles north of the capital, Ouagadougou. "A" Company is to travel in the morning via convoy from the MEU Forward Operating Base at Djibo to set up security for the NGO food trucks that will arrive in the afternoon.

Village of Som – aerial view

Action Vignette

Arriving in mid-morning, "A" Company quickly establishes a perimeter and begins setting up the food and water distribution and medical area on the eastern outskirts of the village. As part of the Company-Level Operations Center (CLOC), Capt. Jones has available a new NIMSS system that will support on-going situational analysis and interpretation and can offer decision support to the Company Commander. The NIMSS has been configured with mission-specific parameters, and immediately begins to ingest information from CLOC team, such as situation reports (SITREPs) and Intelligence Preparation of the Battlespace (IPB) elements from the Company-Level Intelligence Cell (CLIC) in the CLOC.

The leader of the NGO food truck convoy saw the Marines depart first thing in the morning. Thinking he was supposed to follow them, he hurriedly gathered his people and finished preparations for the drive across the desert. This meant that instead of arriving at 1500 as planned, the food trucks would be arriving late morning before the Marines had time to complete their site preparations. NIMSS, processing data entered from the Intel cell based on Tweets from the NGO convey, is able to include both the early convoy movement into its Situational Context model and a projection of its early arrival in Som. As both of these represent potentially significant deviations from plan, NIMSS offers an ORIENT:alert to the CO, to keep the CO aware of an unexpected situational development so that the CO can become oriented to this context change.

Meanwhile, Capt. Jones and a small team leave to meet with the local council of elders in Som to discuss the details of the food distribution, leaving the Executive Officer in charge of the distribution site. The EO receives the ORIENT:alert from NIMSS, and prepares to adapt the site security plan to the early arrival of the NGO convoy. The EO examines the Plausible Narratives being developed by NIMSS, and notes that one involves the presence of the relief convoy drawing in the involvement of local Warlords seeking to steal the supplies or claim credit for its distribution. Seeing this possible line of situational evolution, the EO further decides to increase reconnaissance beyond the perimeter to avoid being surprised by warlord's forces.

During the meeting in Som, Ibrahim Bah, a well-known warlord, burst into the room demanding to know why he hadn't been hired to provide protection for the food distribution. He informs Capt Jones

that he has two dozen men waiting at the Marines' perimeter to "assist." Capt Jones returns to his site to find a couple dozen heavily armed men on the north side of his perimeter just as Bah said. This NIMSS proactive support, however, has led to effective anticipatory actions by the EO, with the result that Warlord Bah's elements have been met with a pre-positioned USMC unit. The EO conveys his actions to Capt. Jones on a secure channel while the CO is returning from Som.

Just as he is entering the site, the 1st Platoon Commander points down the road into town to the west where several additional "technical" vehicles are headed their direction. The lead vehicle pulls over and a quasi-uniformed individual gets out and approaches Capt Jones. He introduces himself as Ghankay Gbagbo, a warlord from the western part of Burkina Faso, and claims that this area is under his "protection." Bah and Gbagbo begin yelling at each other, which is picked up by their men on both sides. Bah claims that this is exactly why Capt. Jones needs his protection.

At the same time, the EO in the COC, is monitoring the radio comms and enters a quick SITREP about this incident (arrival of a second combatant unit, conflicting leaders with the first combatant group) which is entered into NIMSS. After ingesting this information, NIMSS develops a new plausible narrative that is only weakly supported – the possibility of a deception by the two combatant groups to distract the HA mission and capture the relief convoy. NIMSS adds this to its narrative level of context and also generate an OBSERVE: alert, noting that more information on any possible connection between the two external combatant groups could provide greater confidence on the plausibility of this narrative. The CLIC lead notes this OBSERVE: alert and begins working with a cultural intelligent analysis tool within the Intelligence Analysis System (IAS) suite. This tool quickly identifies that the two leaders are, in fact, brothers-in-law and have good relations. This information is quickly passed to the CO from the CLIC, along with the information from NIMSS on a possible deception plan from the local warlords.

Capt Jones queries NIMSS for the narrative path that would produce the best outcome for BLUE force under this narrative, and NIMSS provides a DECSION: alert describing the sequence of events that could produce this best outcome. The alert lists a narrative that successfully achieves a combination of the goals – delaying the NGO convoy and providing it with additional security; concentrating the remainder of the HA company assets on separating the two warlord's units from a direct avenue of approach to the convoy, bringing to bear additional resources as a show of force and potential direct support in case the warlord forces do not disengage – while pursing active negotiation urging the warlord forces to pull back and not risk a politically and militarily significant defeat.

Capt. Jones reviews the overall situational picture available in NIMSS and uses the DECIDE: alert to formulate a Course of Action (COA), which he quickly communicates to his EO for detailing and communication to the units and puts in effect a plan that uses this information. This plan results in the NGO convoy being contacted and directed to immediately halt so as not to become embroiled in any kinetic action that could become a possibility nearer to SOM, plus a Combined Anti-Armor Team (CAAT) in HMMWVs being called in to provide security for the NGO convoy until the situation is resolved. Simultaneously, the CO requests a section of Cobra attack helicopters from the Forward Operating Base at the Djibo airport as a highly visible show of force, and re-establishes negotiations with the warlords to encourage them to withdraw. When the Cobras become visible, both Warlord's units withdraw, and the NGO food convoy is brought into SOM to distribute the food and medical relief needed. Capt Jones and the EO are happy to have achieved their mission objectives, and appreciate the proactive support that the new NIMSS system has provided, allowing them to achieve the desired result without a shot being fired.

Appendix C: Collaborations with Other PDS Program Performers

The CHI Systems team developed the following plans for collaboration with other Proactive Decision Support Program performers:

- *Arizona State University (ASU)* – this collaboration will involve the ASU effort as consumers of context information developed from NIMSS, and NIMSS receiving information from ASU's plan recognition algorithms regarding user activities and tasks;
- *Soar Technologies* – this collaboration will involve the plausible narrative interpretations of the current/historical context developed by NIMSS, with NIMSS past-event narrative and future story-space prospects to Soar Technology, from which they would calculate future importance of different story evolutions and targeted story-states on which to focus as key determinants of future courses or action;
- *Georgia Technological University (GA Tech)* -- this collaboration will involve the GA Tech effort consumers of context information developed by NIMSS, for use as dynamic situational data in their decision making experiments;
- *Dartmouth University (DU)* – this collaboration will involve the incorporation of uncertainty and utility information in the branching structure within the narrative space representation, in which NIMSS would share the narrative space representation and the narrative recognition process with DU, and DU would explore and share results related to the mathematics of propagation of uncertainty and outcome-based utility of future branching paths in the narrative space.
- *Oculus* – this collaboration will involve the development of methods/techniques to visualize the alternative narrative spaces to the consumer of PDS information; in this collaboration NIMSS would provide information on the narrative space representation and Oculus would contribute visualization concepts and (potentially) technology to visualize the different aspects and features of the narrative layer of context to the human PDS consumer.
- *Stanford Research Institute (SRI)* – this collaboration will involve on the interchange of information between the SRI Task Assistant product and the NIMSS context representation product, in which the data on the user task-structure and task focus collected through the Task Assistant would be provided to the context representation as part of the user-activity representation, and the NIMSS context representation would provide situational context information to the SRI for use in tailoring/adaptation of the Task Assistant to current situational context.
- *George Mason University (GMU*) – this collaboration would involve on GMU as consumers of context data from NIMSS' context model product, and using that information to provide tailored decision support and optimization information to the PDS consumers.